

DOCUMENT RESUME

ED 162 852

SE 025 260

TITLE The Pioneer Venus Missions.
INSTITUTION National Aeronautics and Space Administration,
Mountain View, Calif. Ames Research Center.
PUB DATE [78]
NOTE 44p.
EDRS PRICE MF-\$0.83 HC-\$2.06 Plus Postage.
DESCRIPTORS *Aerospace Education; *Aerospace Technology;
Astronomy; Chemistry; Climatic Factors; Earth
Science; Meteorology; Navigation; *Space Sciences
IDENTIFIERS National Aeronautics and Space Administration

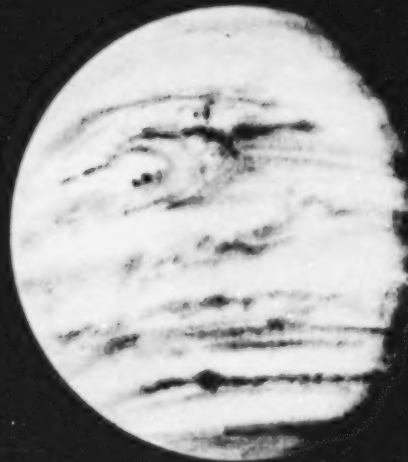
ABSTRACT

This document provides detailed information on the atmosphere and weather of Venus. This pamphlet describes the technological hardware including the probes that enter the Venusian atmosphere, the orbiter and the launch vehicle. Information is provided in lay terms on the mission profile, including details of events from launch to mission end. The pamphlet describes research to be conducted during the mission and relates the importance of the findings to human concerns. (RE)

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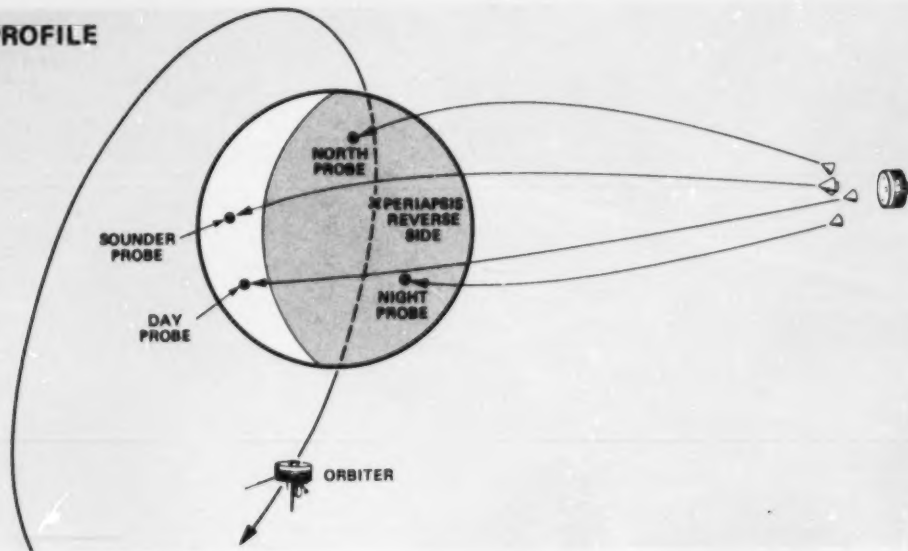


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MISSIONS PROFILE



THE PIONEER VENUS MISSIONS

NASA is sending an orbiter and five atmosphere entry spacecraft to Venus in 1978 to conduct a detailed scientific examination of the planet's atmosphere and weather. The information they gather may help us learn more about the forces that drive the weather on our own planet.

The mission also will survey large areas of Venus' surface for the first time for craters and mountains, and will map Venus' gravity field to calculate the density distribution of the planet's interior, plus its global shape.

The Orbiter is launched in May and inserted into Venusian orbit in December of 1978; the Multiprobe spacecraft is launched in August and its probe craft will enter the Venusian atmosphere five days after arrival of the Orbiter.

The spin-stabilized Multiprobe spacecraft consists of the Bus, the large Sounder Probe, and the three identical North, Day and Night Probes, each carrying a complement of scientific instruments. The probes will be released from the Bus 20 days prior to arrival at Venus.

The Sounder Probe conducts a detailed sounding of

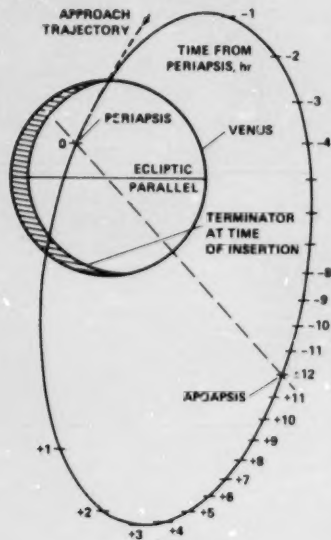
the lower atmosphere, obtaining measurements of the clouds, the atmospheric structure, and the atmospheric composition. Primary emphasis is on the planet's energy balance and clouds. Wind speed will also be measured during the descent.

The three smaller probes, entering at points widely separated from each other, provide information on the general circulation pattern of the lower atmosphere. Since the important motions are believed to be global, only a few observations are required. The Bus provides data on the Venusian upper atmosphere and ionosphere before burning up.

The Orbiter mission is designed to globally map the Venusian atmosphere by remote sensing and radio occultation, and directly measure the upper atmosphere, ionosphere, and the solar wind/ionosphere interaction. Thus, in combination with measurements made at lower altitudes by the four probe craft and the Bus, Pioneer Venus will provide a detailed characterization of the entire Venus atmosphere.

In addition, the Orbiter will study the planetary surface by remote sensing, utilizing radar mapping

ORBIT DESIGN



techniques. This should provide important information on Venus cratering and surface structure.

The Orbiter will be placed in a highly inclined elliptical orbit with the lowest point in Venusian mid-northern latitudes at about 150 km (90 mi) altitude. Operation in orbit should allow investigation over at least one complete rotation of Venus on its axis (243 Earth days).

Pioneer Venus is the first United States mission developed specifically to investigate directly the atmosphere of Venus on a planetary scale. The two spacecraft arrive at Venus in early December of 1978. To accomplish this timing, the Orbiter is launched on a trajectory which takes it more than 180 degrees around the solar system in seven months. The probe vehicle's trajectory is a direct path from the Earth to Venus requiring only four months.

The Orbiter weighs 582 kilograms (1280 pounds) and carries 43 kg (95 pounds) of instruments.

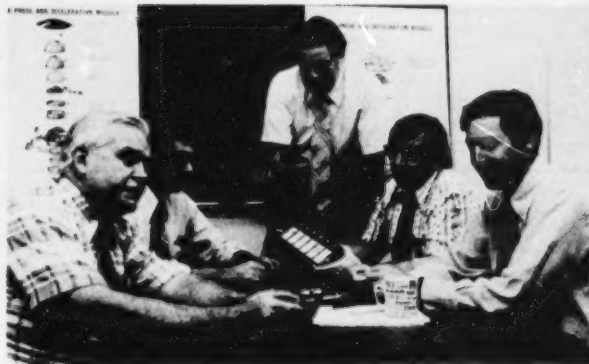
The Multiprobe splits into five atmosphere entry craft (the Bus and the four Probes) eight million miles from Venus. There the vehicles are targeted to locations which are spread over the planet's entire Earth-facing hemisphere.

During their 57-minute descent through the atmosphere, the four probes will provide valuable information on winds and circulation patterns. The probes are not designed to survive after impact.

The Sounder Probe carries about 28 kg (62 lbs) of instrumentation as part of its 291 kg (642 lb) bulk. Its payload includes a mass spectrometer and a gas chromatograph to provide details about the identity of components in the atmosphere.

The three smaller Probes weigh about 86 kg (189 lbs) each, including 2.7 kg (6 lbs) of scientific instruments. The probes' heat shields and pressure vessels comprise most of the weight. The probes will measure atmospheric pressure and temperature. A nephelometer will measure cloud extent and altitude and look at changes in cloud densities. A net flux radiometer will also be on board to investigate the exchange of heat energy between the Sun and the atmosphere.

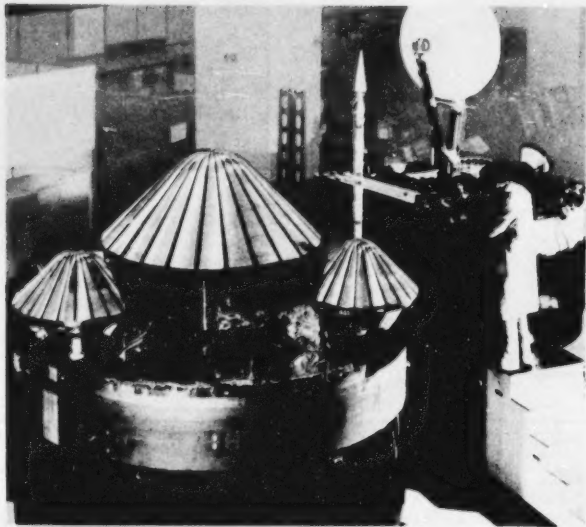
The Bus will also carry a mass spectrometer for studies of the upper atmosphere. After the probe release, the Bus will be targeted for a shallow atmospheric entry, obtaining



Project Management

measurements of the upper atmosphere until it burns up at an altitude of about 120 km (75 mi).

The Pioneer Venus mission is managed for NASA's Office of Space Science by NASA's Ames Research Center, Mountain View, Calif. Spacecraft are built by Hughes Aircraft Company, El Segundo, Calif.



Multiprobe and Orbiter at Hughes Aircraft

THE VENUS SPACECRAFT

THE BUSES

The Pioneer Venus Orbiter and Venus Multiprobe spacecraft share a "basic Bus" design. The Bus portions of each are identical spin-stabilized cylinders containing most spacecraft systems.

Three-quarters of the systems on the basic Bus are common to both spacecraft. These include a thermally-controlled equipment and scientific instruments compartment, solar panels around the Bus exterior, batteries and power distribution system, forward and aft omni antennas, communications systems, data processing systems, and Sun and star sensors for orientation reference. Other common systems are hydrazine propellant tanks plus six thrusters for orientation, course corrections, and spin rate control.

A spin-rate of 15 revolutions per minute maintains the spin axis of both craft perpendicular to the Earth's orbit plane during cruise. This orientation keeps solar cells at right angles to the Sun's rays, for maximum power output. In Venus orbit, the Orbiter spin rate is cut to five RPM, but



Probe Craft Assembly

it continues the same perpendicular orientation.

Both Orbiter and Multiprobe Buses carry S-band radio receivers and transmitters for two-way Doppler tracking, command receipt and data transmission, plus a command memory for 256 commands. Both Buses transmit data at a rate of 2048 to 16 bits per second (BPS).

Navigation for both spacecraft employs the Doppler shift in frequency of spacecraft radio signals. The shift is caused by motion of the spacecraft and measured by ground tracking. It allows computer calculation of speed, distance, and location of the spacecraft.

Both cylindrical spacecraft are about 2.5 meters (8.3 feet) in diameter. The Venus Orbiter, including its high-gain antenna array, is almost 4.5 m (15 ft) high. The Venus Multiprobe is 2.2 m (7.5 ft) high. Launch weight of the Orbiter is about 582 kg (1280 lbs) with 45 kg (100 lbs) of scientific instruments. Weight after orbital insertion is 368 kg (810 lbs). Weight of the Multiprobe is 904 kg (1990 lbs) with 49 kg (108 lbs) of scientific instruments.



THE MULTIPROBE SPACECRAFT

The Multiprobe is the basic Bus adapted to carry the Sounder Probe and the three smaller Probes. The Multiprobe Bus also carries two upper atmosphere composition experiments. In addition to the standard Bus systems, the Multiprobe Bus has an aft-mounted, medium-gain antenna. At probe separation, the Sounder Probe ejects from the Bus by springs. The smaller Probes are spun off by Bus rotation.

THE PROBES

All Four Probes are individual spacecraft, and transmit their data directly to Earth.

The Sounder Probe weighs about 314 kg (691 lbs) and is about 1.4 m (4.7 ft) in diameter. It returns data at 256 bits per second, and its seven scientific instruments weigh 29 kg (64 lbs).

The North, Day, and Night Probes are identical. Each is 0.8 m (30 inches) in diameter and weighs 90 kg (200 lbs). Each carries three scientific instruments, weighing 3.5 kg (7.7 lbs). The smaller Probes transmit data at 64 BPS during flight down to 30 km (18 mi) altitude and 16 BPS from there to the surface.

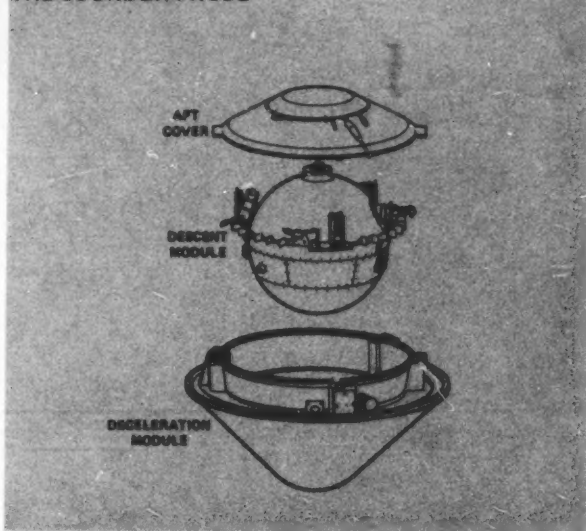
All four probes employ sealed spherical pressure vessels. They are made of titanium, to withstand Venus' 480°C (900°F) heat, its corrosive atmosphere, and 100-times-Earth's atmosphere pressure. Inside, the vessels carry the spacecraft systems and scientific instruments on fore and aft shelves. Probe spacecraft systems include power, command, data processing, and communications.

Entry forces peak at 315 G at about 78 km (48 mi) above the surface for the Sounder Probe, and at 200 to 560 G, depending on atmosphere entry angle, for the smaller Probes. For entry heating and stabilization, the probes have blunt-nosed, 45° conical carbon-phenolic heat shields. Aft bodies are coated with heat-resistant elastomeric coatings.

The Sounder Probe is slowed during descent by a parachute, and jettisons its heat shield after entry. The three smaller Probes carry their heat shields to Venus' surface. All four are spin-stabilized for entry.

All instruments on all four probes require either observing or sampling access to the hostile Venus atmosphere. This access is one of the hardest problems of the mission. The Sounder Probe has 15 sealed windows or other

THE SOUNDER PROBE



pressure vessel penetrations, the smaller Probes, eight. There are 14 sapphire and one diamond windows.

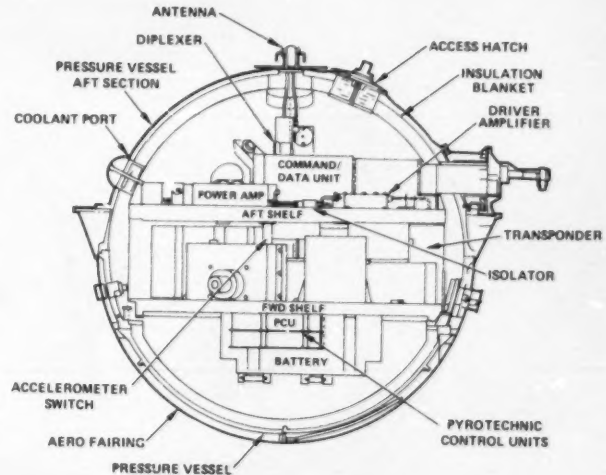
Each probe is powered by a 28-volt silver-zinc battery. The Sounder Probe battery has four times the capacity of each smaller Probe battery.

Command systems on the four probes consist of on-board logic and automatic timing and sensing devices which can provide up to 64 commands, as needed. The probes cannot be commanded from Earth after separation from the Bus.

Each of the four probes communicates directly with Deep Space Network antennas using solid state transmitters and hemispherical-pattern antennas.

Probe data-handling systems can accept data from scientific instruments and engineering systems on 72 channels, and can store 3,072 data bits. The Sounder Probe has a more powerful radio transmitter than those for the smaller Probes, to handle its higher data rate. It also carries a radio receiver, for two-way Doppler tracking only. Reference frequency for one-way Doppler tracking of the smaller Probes is provided by stable oscillators.

SOUNDER PROBE PRESSURE VESSEL



VENUS ORBITER

The Orbiter consists of the basic Bus adapted to the Orbiter mission.

At the forward end of the spacecraft, the Orbiter's high-gain, parabolic dish antenna is mounted on a ten-foot mast, aligned with the spin axis. A bearing and power transfer assembly mechanically despins the antenna. With the spacecraft spin-stabilized perpendicular to the Earth's orbit plane, the antenna reflector can focus constantly on Earth during both interplanetary cruise and on orbit.

The Orbiter's 12 scientific instruments are carried inside the spacecraft's equipment compartment. Two magnetometer sensors are mounted on a 4.7 m (15.5 ft) boom to prevent magnetic interference from the spacecraft.

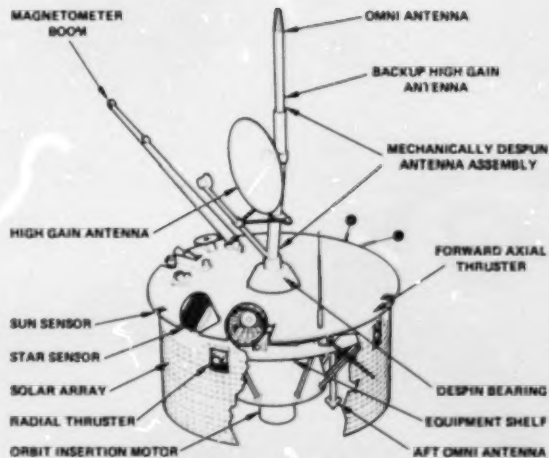


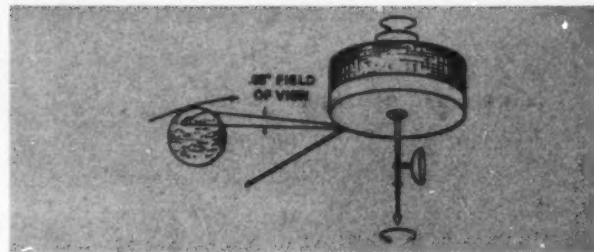
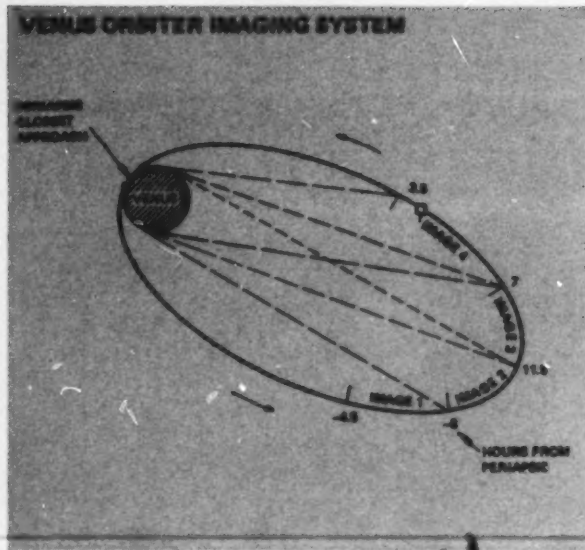
In addition to its basic Bus S-band transmitter, the Orbiter also has an X-band transmitter. This allows study of Venus atmosphere effects on the radio signal at two different frequencies during planet occultations. An 18,000 Newton (4000 lb) thrust rocket motor on the aft end of the spacecraft puts the Orbiter in planet orbit.

Like the Multiprobe, the Orbiter has two 250 watt-hours nickel-cadmium batteries. It has a slightly larger solar array than the Multiprobe, 7.4 square m (79.6 sq ft), to meet its larger power demands. The array provides 312 watts at Venus.

The Orbiter also has a data storage unit with a one-million-data-bit memory to store for later playback to Earth. Data storage will be especially important during communications blackout periods of up to 26 minutes when the spacecraft is behind Venus.

ORBITER SYSTEMS





The cloud photopolarimeter uses the motion along the Orbiter's flight path around Venus for complete mapping of the planet. The instrument uses a 3.7 cm (1.5 in.) telescope with an ultraviolet (UV) filter for tracking the four-day rotation of Venus' clouds, shown by UV-absorbing markings in the dense upper atmosphere. The instrument can make five planetary images in each spacecraft orbit. The field of view is about one-half milliradian, corresponding to a resolution of about 30 km (19 miles) directly below the Orbiter. The instrument will also measure scattered sunlight polarization based on cloud and haze particle size, shape and density.

When the Orbiter is at periapsis the instrument observes in visible light the high-haze layers of the atmosphere. These "limb scans" have a resolution as small as 0.5 km (0.3 miles).



Venus Cloud Circulation

WHY PIONEER VENUS?

Venus Holds Clues to Earth's Weather. When two Pioneer spacecraft arrive at Venus in 1978 to probe that planet's murky atmosphere, the information they gather may also help us learn more about planet Earth.

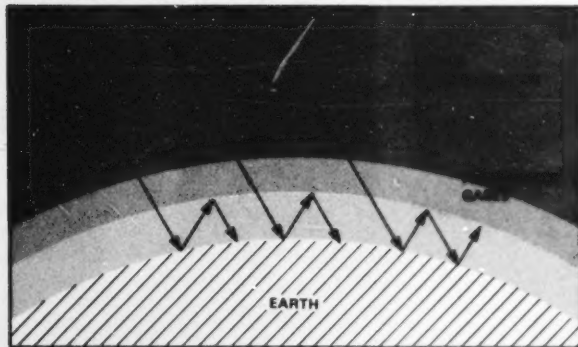
NASA believes the study of weather patterns on other planets — and on Venus in particular — can provide clues to the mysteries of our own weather system.

On Earth, the basic causes of weather patterns are not clearly understood, as evidenced by the shifting tornado and hurricane paths that catch communities unaware every year.

Many factors complicate Earth's meteorology. Mixing of oceanic and continental air masses, partial cloud cover, axial tilt, and rapid planet rotation make our atmosphere difficult to study.

But Venus is simpler to study because it has a basic atmosphere that is 95 percent carbon dioxide, a very slow rotation (243 Earth days equal one rotation of Venus), very little tilt to its axis and no oceans.

GREENHOUSE EFFECT TRAPS SOLAR ENERGY



The "runaway greenhouse" theory argues that Venus' atmosphere allows some sunlight to reach the planet's surface but stops most of the outgoing heat radiation. The thick cloud layers and carbon dioxide atmosphere block surface heat from radiating back into space, creating 485 degree C (900 degree F) surface temperatures. Some scientists warn that as we burn vast amounts of fossil fuels we increase CO₂ levels in the Earth's atmosphere, and may be creating a runaway greenhouse like that on Venus.

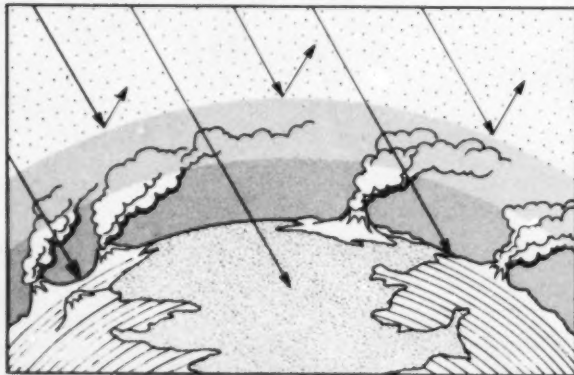
If scientists can understand how these variables affect the atmosphere of our closest planetary neighbor, they hope to be able to define more clearly the impact of the numerous variables in the Earth's weather system.

Further insights into basic weather processes will come not only from intensive observations of the Earth itself but also through NASA's current first-hand studies of Jupiter's fast-spinning atmosphere and Mars' easily-observed, largely cloudless atmosphere which is sometimes rendered so opaque by very large dust storms that the surface can no longer be seen.

Questions Important to Man. Comparison of Venus' atmospheric characteristics with those of Earth may help answer other important scientific questions. Among these are:

- Why has Venus taken a different evolutionary path than Earth? Venus is similar to Earth in size and mass, and was probably formed out of the same homogeneous mixture of gas and dust. It has often been called Earth's sister planet.

LITTLE ICE AGE 1450-1615



The "Little Ice Age" on Earth saw a dramatic cooling of the Earth's climate. England's Thames River froze over, European villages were overrun by glaciers and no ships could reach Greenland, which had been colonized centuries before. Many scientists believe the large number of volcanic eruptions in this period were largely responsible for the planet-wide cooling. Volcanoes spewed into the atmosphere

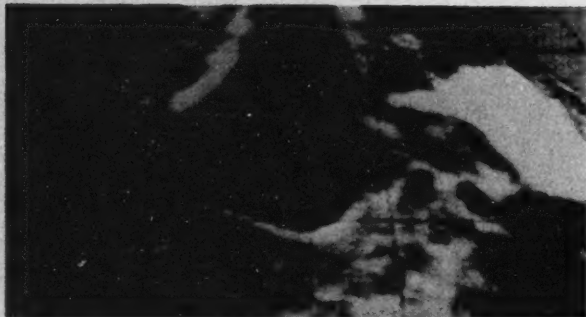
But recent American and Soviet space probes have revealed atmospheric and surface conditions that differ markedly. The surface of Venus is sizzling hot at 480°C (900°F), the atmosphere about 100 times heavier than that of Earth, and largely made up of carbon dioxide.

The processes that resulted in such unusual conditions are difficult to explain. Scientifically, Venus is the most puzzling planet in the solar system.

Other important questions that Pioneer Venus may help answer are:

- What are the stabilizing and destabilizing feedback mechanisms that determine a planet's climate?
- Did liquid water ever flow on the surface?
- Where is the water that may have been on Venus originally?

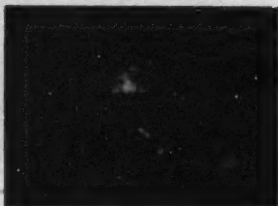
great quantities of dust which turn into tiny sulfuric acid particles. These reflect sunlight away from the Earth's surface, causing it to cool. The pale yellowish clouds which obscure the surface of Venus are thought to consist of virtually identical sulfuric acid droplets. Studying Venus' clouds may help us better understand the role these droplets play in Earth's weather.



(A)



(B)



(C)

While it is not possible to see through the clouds of Venus, powerful Earth-based radar can easily penetrate to the surface. Radar maps of Venus reveal features interpreted as extensive lava flows, canyons, major chasms and large shallow craters.

(A) A 1976 radar probing reveals a bright area thought to be a gigantic lava flow and a dark area which may be a large impact basin similar to those on the moon. The basin, the size of Hudson Bay, is surrounded by sharp ridges several hundred kilometers long.

(B) This high resolution radar image shows a dark chasm over 1000 km (620 miles) long running north-south across the equator. It appears to be 1-2 km (0.6-1.2 miles) deep and branches into two at its southern end. The main trough is roughly 150 km (95 miles) wide.

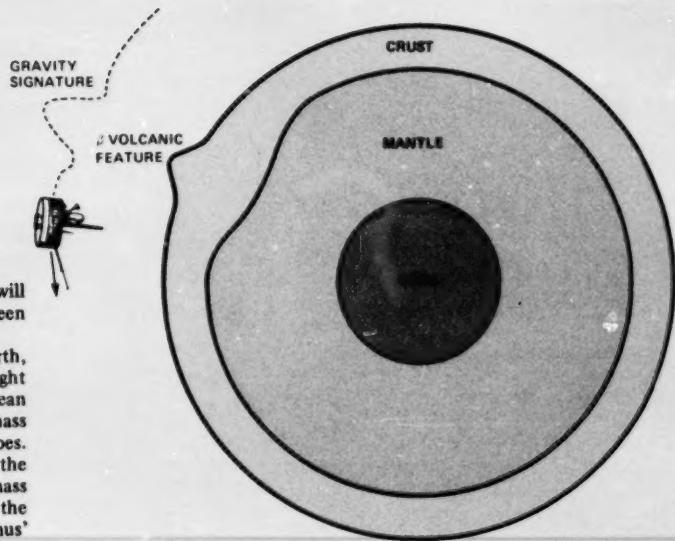
(C) This picture shows craters 35 km to 100 km (22 to 62 miles) in diameter. All are shallow, i.e., the ratio of crater diameter to depth is about 100 to 1, compared to the Moon's 10 to 1.

In photos (B) and (C), numbers show Venusian latitudes.

The Orbiter's internal density distribution experiment will determine the planet's global shape and the relationship between Venus' surface features and their corresponding internal densities.

The experiment will use radio signals sent first from Earth, received by the Orbiter, and retransmitted back to Earth. Slight Doppler shifts in frequency of these retransmitted signals mean velocity changes due to "gravity signatures" caused by mass concentrations, perhaps prominent surface features such as volcanoes.

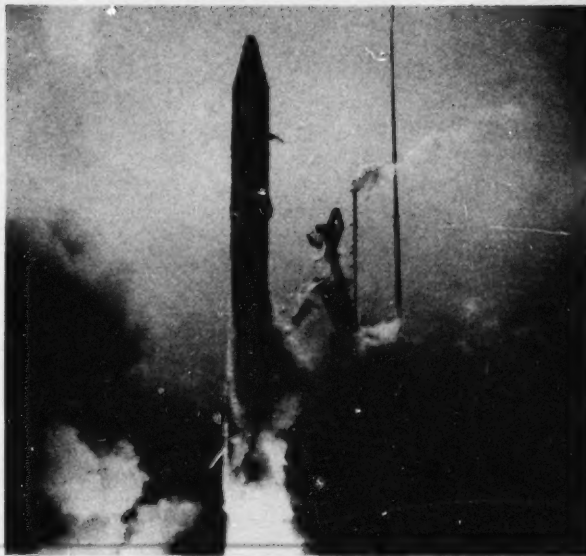
Analysis of these velocity changes will allow mapping of the planet's gravity field providing information on the internal mass distribution of Venus, the likely composition and temperature of the interior, and possible physical processes which governed Venus' planetary evolution.



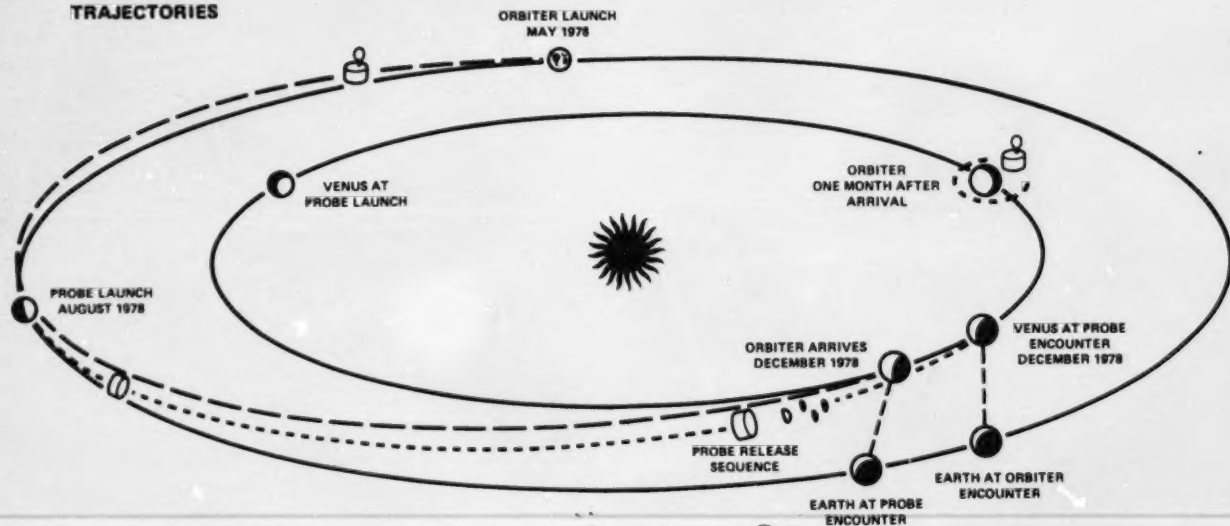
THE LAUNCH VEHICLES

Launch vehicle for both the Orbiter and the Multiprobe launches is the Atlas SLV-3D/Centaur D-1AR vehicle. Both spacecraft will lift off on circular parking-orbit ascent trajectories from NASA facilities at Cape Canaveral Air Force Station, Florida. Both launches are from Complex 36, CCAFS, under direction of the Expendable Vehicles Directorate, NASA Kennedy Space Center, Florida.

The Atlas-Centaur vehicles are about 37.5 meters (125 feet) high and three meters (ten feet) in diameter. The SLV-3D Atlas has two booster engines, a sustainer engine, and two small vernier engines with an overall thrust of 1,917,000 Newtons (431,040 lbs). The upper stage 9.3 meter (31 foot) Centaur uses liquid hydrogen/oxygen propellants and has a thrust of 130,000 Newtons (30,000 lbs). Thrust is provided by two engines which gimbal for pitch, yaw and roll control and have a restart capability.



PIONEER VENUS TRAJECTORIES



MISSION EVENTS AND OPERATIONS

At Venus, the primary Orbiter mission lasts 243 Earth days, one Venus rotation on its axis, while the four Probes measure Venus' atmosphere from top to bottom in just 57 minutes each.

ORBITER EVENTS

Orbiter events en route to Venus include launch, spin-up to 15 RPM, one course correction during the first month, checkout for orbit insertion, spacecraft reorientation, and rocket burn for orbit capture. In orbit, spin rate is cut to five RPM, and thrusts for orbit trim will be commanded every two weeks.

Both during cruise and in orbit, radio commands every few days adjust the pointing of the despun, parabolic high-gain antenna to keep the radio beam centered on Earth.

The Orbiter's highly inclined (75°) elliptical orbit allows radar mapping of one north-south strip of Venus' surface per day from about 50° north of the equator to 6° south. During the primary Orbiter mission at Venus of 243

days, it will map a belt completely around the planet. The orbit has a 24-hour period for timing orbital events with Earth events, and for returning periapsis data when two 64-meter antennas see the spacecraft at the same time. Orbital high point is 67,000 km (41,500 mi); low point (periapsis) is 150 km (90 mi).

MULTIPROBE EVENTS

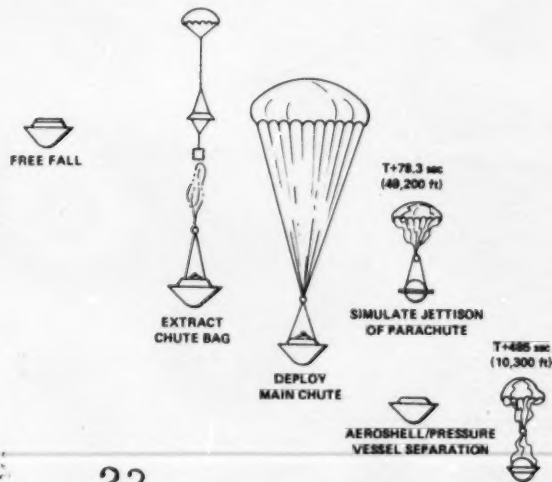
The probes separate from the Multiprobe Bus 20 days before planet arrival, fly independently to their target points, and are not heard from again until 20 minutes before atmosphere entry. Entry speeds are around 41,600 km/hour (26,000 mph). One of the three smaller Probes enters at 58° north latitude on the night side. This may be far enough north to reach the polar vortex where upraised equatorial air is believed to spiral down to Venus' surface again. The

Multiprobe Bus enters at about 45° south latitude at a shallow angle of about 10° , and makes its measurements down to an altitude of 120 km in about two minutes before it starts to burn up. Only the Bus makes atmospheric and ionospheric composition measurements in the 120 to 150 km altitude region.

Earth-Venus cruise events for the Multiprobe include the following: launch, spin-up to 15 RPM, one or two course corrections in the first 30 days, reorientation for use of aft medium-gain antenna, and checkout of instruments on all four Probes and Bus. Other events are aim and launch Souder Probe at about 13 million km (8 million mi) from Venus; retarget, spin up to 48 RPM, aim, and release North, Day, and Night Probes; retarget, spin down to 15 RPM, and orient for Bus entry.

After separation of the four Probes, all probe commands come from on-board electronics. Two hours before entry, on-board commands activate batteries and warm up probe radios. At 22 minutes before entry, scientific instruments are warmed up and calibrated; high speed entry occurs at about 26,000 mph, with about a ten-second

DEPLOYMENT AND SEPARATION SEQUENCE

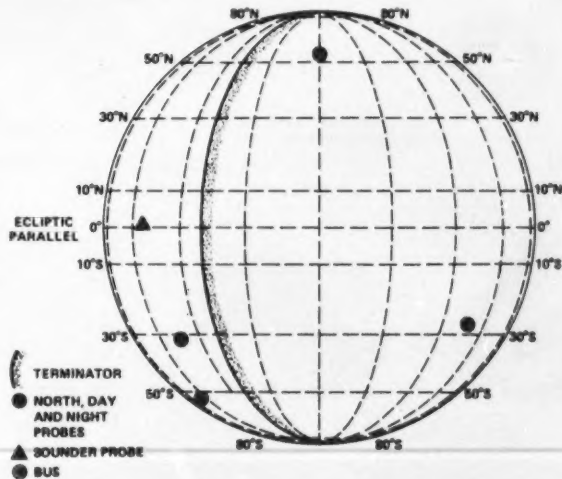


communications blackout, during which data is stored. After entry, instrument booms on the smaller Probes deploy and instruments begin measurements. At 30 km altitude, data rate of the smaller Probes change to 16 BPS. At 56 minutes after atmosphere entry, all four Probes impact on Venus' surface. Some seismic and other data may be returned from the surface, though probes are not designed to survive there.

Sounder Probe events after entry include parachute deployment (smaller Probes have no chutes), and heat shield jettison at 67 km (42 mi), parachute jettison at 47 km (26 mi), and impact on Venus' surface at 32 kph (20 mph) 57 minutes after entry.

The Bus enters, measures upper atmosphere and ionosphere, and burns up 90 minutes after the last probe enters.

VIEW FROM EARTH OF PROBE ENTRY LOCATIONS

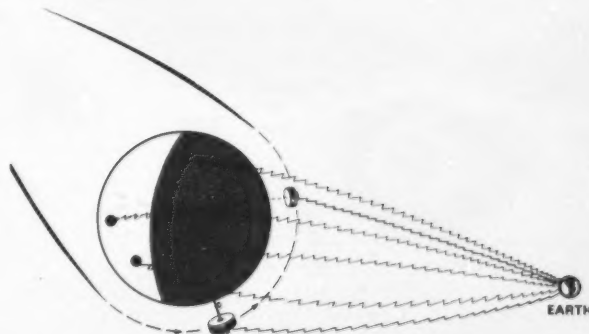


DATA RETURN, COMMAND, AND TRACKING

NASA's Deep Space Network (DSN), operated by NASA's Jet Propulsion Laboratory in Pasadena, Calif. will track and receive data directly from all six Pioneer Venus spacecraft. Tracking will be conducted by the DSN's global networks of 26-meter and highly sensitive 64-meter antennas. The 64's will be used during critical phases of the mission, such as reorientation, velocity corrections, orbit insertion, and flights of the probes through the Venus atmosphere — as well as during the later parts of the Orbiter mission when Venus is too far away for the 26-meter antennas to hear high data rates. At mission end, Venus is 203 million km (126 million) miles farther from Earth than at arrival.

The 26's will receive 1024 to 2048 data bits per second (BPS) during the first 50 days in Venus orbit. After this, tracking of the Orbiter will be taken over by the 64's, which can hear 2048 BPS for the first 130 days in orbit, and 1024 BPS thereafter.

PROBE DATA RETURN



Mission Control will be at Kennedy Space Center, Florida for launch and at the Pioneer Mission Operations Center at Ames for the rest of the mission.

Incoming telemetry data from the spacecraft is formatted at DSN stations for high-speed transmission to Ames computers. These computers will check for critical changes and provide data for analysis by spacecraft, experiments, and ground systems specialists. Their analyses will be used immediately for spacecraft control. Outgoing commands are verified by Ames computers and sent to DSN stations for transmission.

Venus wind speeds will be determined by computation of exact flight paths of the four Probes. The flight paths will be calculated by radio triangulation among the probes, the Bus, and four ground stations, including two supplementary NASA stations at Guam and Santiago, Chile.



MULTIPROBE EXPERIMENTS – WHAT THEY TELL

SOUNDER PROBE

Mass Spectrometer – directly measures atmospheric composition and vertical structure in the lower 67 kilometers (42 miles) of the Venus atmosphere. The measurements will determine abundances and vertical distribution of noncorrosive gases, and composition, scale size and physiochemical properties of the cloud layers. They will identify chemically active constituents, and determine isotope ratios of inert gases, and crustal abundances of volatile elements.

Gas Chromatograph – measures composition of the lower atmosphere of Venus to (a) find the major gaseous sources of infrared opacity in order to help understand Venus' very high surface temperature, (b) infer the composition of cloud layers, (c) obtain information about differentiation of the interior of Venus by measuring gaseous radioactive decay products, (d) deduce the similarity between Venus and Earth from abundance of sulfur compounds, and (e) infer how Venus' atmosphere evolved.

Cloud Particle Size Spectrometer – measures particle size and number density in the clouds and lower atmosphere of Venus from 67 km (42 mi) down to the surface, defining levels of cloud layers. Information on particle size and mass, with cloud characteristics such as cloud particle mass content, optical depth and spectral properties, should provide clues to basic cloud formation processes.

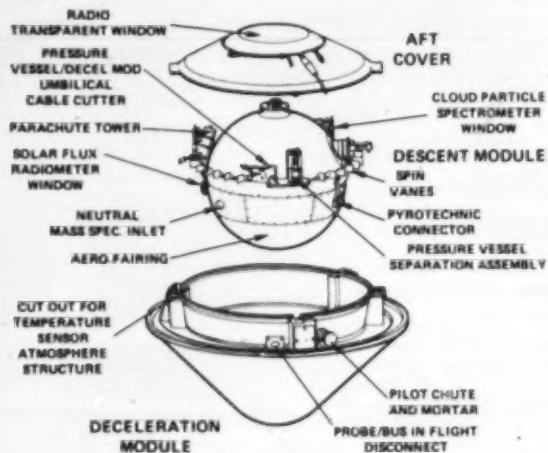
Solar Radiometer – measures the deposition of solar energy with depth in the atmosphere of Venus, obtains information on the vertical cloud structure, and may find scattering properties of cloud particles.

Infrared Radiometer – determines divergence of the thermal flux in order to define heat sources and heat-sinks, to detect cloud layers and infer their composition, to determine opacity of clouds in the infrared spectral region, and to estimate abundance of water vapor in the lower atmosphere.

ALL PROBES

Atmosphere Structure Instrument – measures thermal structure of the atmosphere from 200 km (124 mi) down to the surface at the four entry locations of the Large and

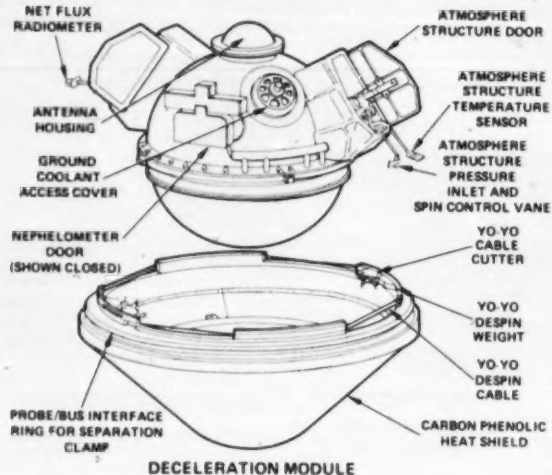
SOUNDER PROBE EXPERIMENTS AND SYSTEMS



Small Probes. Instrument also measures temperature as a function of pressure precisely enough to help understand the role of circulation in maintaining the high temperature of the lower atmosphere. The experiment also measures temperature, pressure, and density as a function of altitude; and determines vertical flow in the lower atmosphere, and scale and intensity of turbulence.

Nephelometer (Cloud Sensor) – explores the vertical structure of the clouds to find cloud particles (solid or liquid) in the region from 67 km (42 mi) to the ground. Measurements on all Four Probes help determine whether cloud stratification is planet-wide. Background scattered sunlight is monitored at wavelengths of 3500 and 5300 Angstroms, by the two Probes on the sunlit side with a vertical resolution of 150 meters (500 ft).

NORTH, DAY, AND NIGHT PROBE EXPERIMENTS AND SYSTEMS



NORTH, DAY, AND NIGHT PROBES

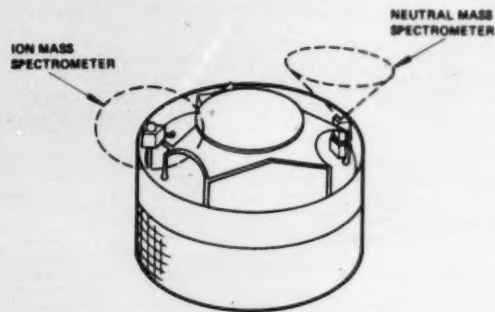
Net Flux Radiometer – (1) determines the global and vertical distribution of sources and sinks of radiative energy within the atmosphere and at the surface of Venus, and (2) relates these results to observed atmospheric motions, temperature structure and cloud characteristics. Structure and motions of the atmosphere are fundamentally linked with radiative interchanges of heat within it.

THE BUS

Upper Atmosphere Mass Spectrometer – finds densities of atmospheric constituents from 500 km (300 mi) down to 120 km (75 mi). Atmosphere composition is not measured in the bottom 18 miles of this range by probes or Orbiter. Scale height temperatures, height of the turbopause, eddy diffusion and atmospheric composition at the ionospheric peak will be calculated.

Ion Mass Spectrometer – measures distribution and concentration of ionic constituents from about 2000 to 120 km (1240 to 75 mi) to find physical and chemical processes of Venus' ionosphere and its interactions with the solar wind.

BUS EXPERIMENTS WITH VIEW ANGLES



MULTIPROBE RADIO SCIENCE, ALL PROBES (Experiments which use spacecraft radio signals)

Differential Long-Baseline Interferometry (DLBI) — Wind velocities are measured by computing exact flight paths during the descents of all four Venus Probes. Experimenters employ ground-based radio-interferometric tracking (triangulation from three tracking stations). Wind velocities will be combined with simultaneous temperature, pressure, heat flux and composition measurements to test models of atmospheric circulation.

Atmospheric Attenuation Experiment — studies the atmospheric structure of Venus as it affects intensity and refraction of probe telemetry signals, and assesses communications for design of future probes.

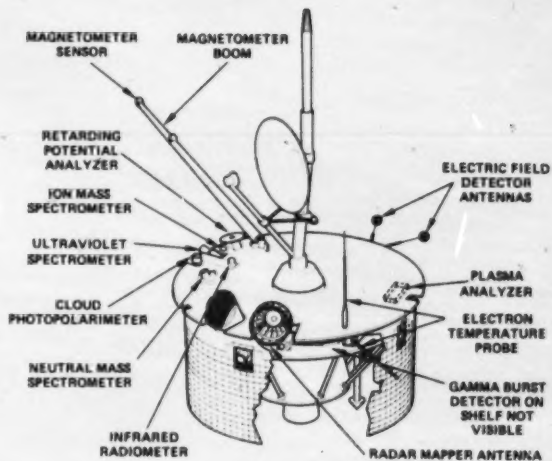
Atmospheric Turbulence Experiment — measures changes in probe radio signals to determine small scale turbulence of Venus' atmosphere, variations of intensity of turbulence with altitude, and wind velocity transverse to the line-of-sight path.

ORBITER EXPERIMENTS

Neutral Particle Mass Spectrometer — finds densities of neutral particles in the upper atmosphere from 150 km (93 mi) at periapsis to 500 km (300 mi). This will help define dynamic chemical and temperature states of the upper atmosphere. Vertical distribution of light constituents will help show the gas escape mechanism. Height of the turbopause (limit of atmosphere-mixing) will be determined by comparing density distribution of inert gases with similar measurements on the Large Probe.

Charged Particle Mass Spectrometer — measures distribution of ions in the upper atmosphere of Venus, to help understand Venus' ionosphere and its interaction with the solar wind.

Retarding Potential Analyzer — determines sources of energy input to the ionosphere, plasma transport and solar wind-ionosphere interaction processes, by measuring temperatures and concentrations of ions, ion drift, electron concentration and temperature, and ambient photoelectrons.



Electron Temperature Probe — measures thermal structure of the ionosphere to help understand how it is heated and cooled — probably by interaction with the solar wind at higher altitudes and by solar ultraviolet at lower altitudes. Electron concentration and ion mass also will be derived.

Ultraviolet Spectrometer — investigates temperature, energy balance, distribution and escape rate of atomic hydrogen in the thermosphere and exosphere, ultraviolet scattering properties of the cloud tops, hazes, and adjacent atmosphere and the spectral nature, distribution and movement of ultraviolet albedo features.

Solar Wind/Plasma Analyzer — measures the solar wind and its interaction with Venus. Bulk velocity, flow direction, flux and temperature will be measured.

Magnetometer — measures the planetary magnetic field; finds ionospheric current systems, energy and mass balance of the upper atmosphere; and investigates solar wind-Venus interaction.

Temperature Sounding Infrared Radiometer — obtains vertical temperature profiles in Venus' upper atmosphere from the dense cloud tops to the thermosphere (where temperature rises with height). The instrument gets horizontal temperature gradients in the atmosphere at seven pressure levels, from about one millionth of a millibar to 250 millibars in order to chart Venus' four-day circulation. It will find the total amount of sunlight reflected from Venus (albedo), study the top cloud layers and their global variability, and find the planet's energy budget and its correlation with its ultraviolet markings. Distribution of water vapor above the dense clouds will be estimated.

Cloud Photopolarimeter/Imaging — determines properties and distribution of cloud and haze particles in and above the visible clouds. Ultraviolet atmospheric markings and circulations are observed and apparent cloud motions measured. These take the form of pictures of the planet.

Radar Mapper — provides radar images of a band of Venus' surface circling the planet near the equator, from 6°

south to 44° north latitude, including many areas never seen before to this accuracy. It will resolve surface features as small as 20 km (13 mi) and derive surface heights to an accuracy of about 110 meters (360 ft). From these it can estimate global shape, the dielectric constant, small-scale slopes, surface emissivity and temperature.

Electric Field Detector — studies interaction between the solar wind and ionospheric plasma; locations of Venus' bow shock, ionopause and wake cavity boundary; heat flux, wave-particle interaction and upstream turbulence at the

Venus-solar wind boundary, as well as electromagnetic noise bursts from Venus' atmosphere.

Gamma-Ray Burst Detector — observes intense, short-duration bursts of high energy photons from astronomical sources. The bursts were discovered in 1973, and their sources are unknown. Correlations of Venus Orbiter with near-Earth observations can provide directional determinations accurate enough for attempts at telescope identification of sources of bursts.

ORBITER RADIO SCIENCE

Internal Density Distribution Experiment — uses precise measurements of orbit changes to find Venus' internal mass distribution. Physical processes producing distribution, relation of surface shape to internal density distribution and compensations in Venus' topography will be inferred.

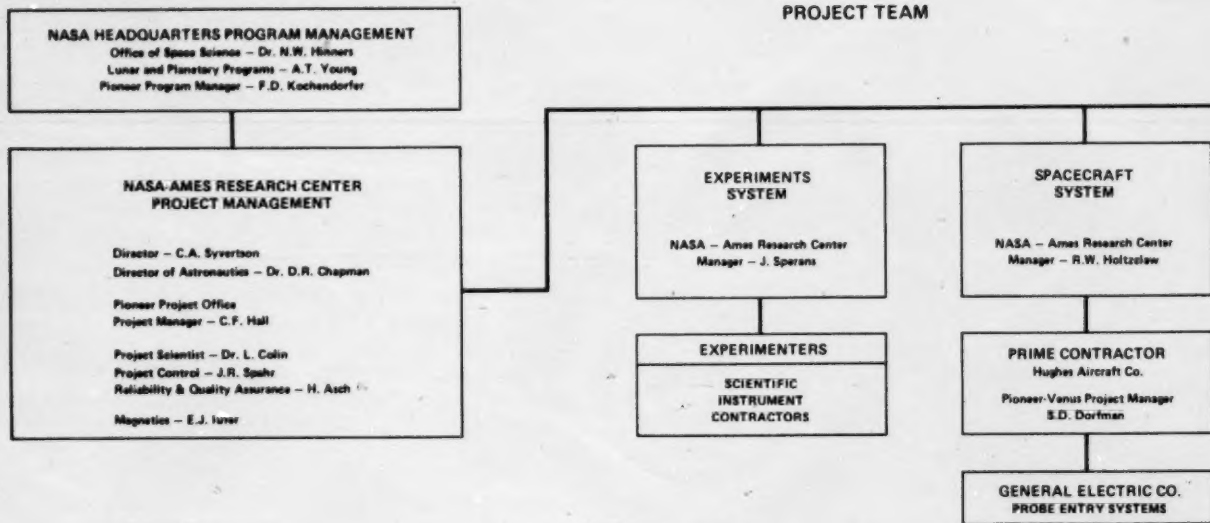
Celestial Mechanics Experiment — models the gravity field of Venus, estimates direction and magnitude of Venus' spin vector, amount of polar motion of Venus, and density profile of the upper atmosphere (from observations of orbital decay). It will improve planetary orbit definitions (especially of Venus and Earth), measure relativistic effects of solar gravity on the tracking signal and compare the coordinate system of the planet orbits with an inertial coordinate system referenced to extragalactic radio sources.

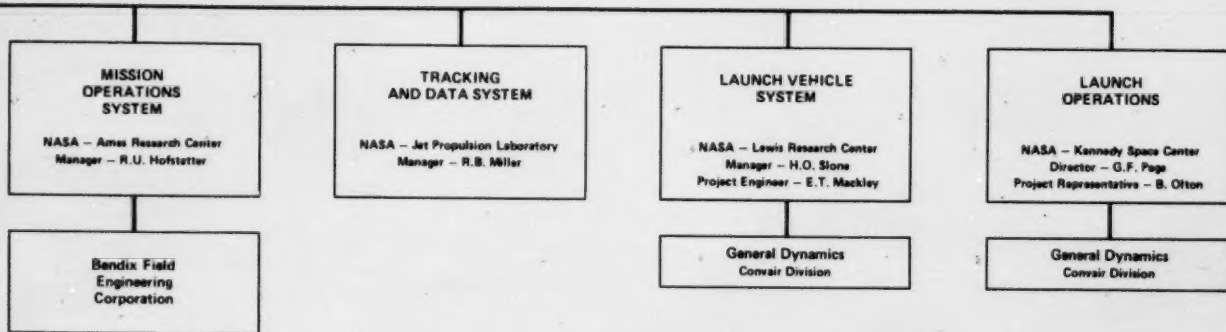
Radio Occultation Experiment — determines refractivity profiles from phase perturbations of the S and X-band telemetry to obtain temperatures, pressures and densities in

the atmosphere above 35 km; measures dispersive absorption from signal attenuation during occultation to obtain data on radio absorptive layers below 50 km; and measures electron-density height profiles from dispersive S and X-band phase effects.

Atmospheric and Solar Corona Turbulence Experiment — measures small-scale turbulence of the Venus atmosphere above 35 km (20 mi), showing variations of turbulence with altitude, latitude and longitude. The experiment also determines solar corona turbulence and solar wind velocity near the Sun.

Drag Measurement Experiment — analyzes drag on the Orbiter by the upper atmosphere of Venus using S and X-band Doppler data, the first such measurements of another planet. The experiment should provide data on density and characteristics of Venus' thermosphere; and on the relation of upper atmosphere density to variations in the solar wind and solar ultraviolet, as well as to semi-annual variations, and super rotation of the thermosphere.





SCIENTIFIC INSTRUMENTS AND EXPERIMENTERS MULTIPROBE SPACECRAFT

Sounder Probe

Mass Spectrometer	Dr. John Hoffman University of Texas, Dallas
Gas Chromatograph	Vance Oyama NASA-Ames Research Center
Atmosphere Structure	Alvin Seiff NASA-Ames
Solar Flux Radiometer	Dr. Martin Tomasko University of Arizona
Infrared Radiometer	Robert Boese NASA-Ames
Cloud Particle Size Spectrometer	Dr. Robert Knollenberg Particle Measuring Systems, Inc.
Nephelometer (cloud sensor)	Dr. Boris Ragent, NASA-Ames Dr. Jacques Blamont University of Paris

North, Day and Night Probes

Atmosphere Structure	Alvin Seiff NASA-Ames
Nephelometer	Dr. Boris Ragent, NASA-Ames Dr. Jacques Blamont University of Paris
Net Flux Radiometer	Dr. Verner Suomi University of Wisconsin
Bus	
Mass Spectrometer	Dr. Ulf von Zahn University of Bonn, West Germany
Ion Mass Spectrometer	Harry Taylor NASA-Goddard



Multiprobe Radio Science

These experiments measure interaction of spacecraft radio signals with Venus and its atmosphere, using the spacecraft as instruments. Dr. Gordon Pettingill, MIT, is team leader.

Differential
Long-Baseline
Interferometry
(wind speeds)

Dr. Charles Counselman, MIT

Atmospheric
Attenuation

Dr. Thomas Croft
Stanford Research Institute

Atmospheric
Turbulence

Dr. Richard Woo, JPL



ORBITER SPACECRAFT

Neutral Mass Spectrometer	Dr. Hasso Nieman NASA-Goddard
Ion Mass Spectrometer	Harry Taylor, NASA-Goddard
Retarding Potential Analyzer	Dr. William Knudsen Lockheed Missile and Space Co.
Electron Temperature Probe	Larry Brace NASA-Goddard
Ultraviolet Spectrometer	Dr. Ian Stewart University of Colorado
Radar Mapper	Dr. Gordon Pettengill Massachusetts Institute of Technology
Magnetometer	Dr. Christopher Russell University of California, Los Angeles
Cloud Photopolarimeter, Imaging Instrument	Dr. James Hansen Goddard Institute of Space Studies

Solar Wind/Plasma Analyzer	Dr. John Wolfe NASA-Ames
Temperature Sounding Infrared Radiometer	Dr. Fredric Taylor Jet Propulsion Laboratory
Electric Field Detector	Dr. Frederick Scarf, TRW Inc.
Gamma Ray Burst Detector	Dr. W.D. Evans Los Alamos Scientific Laboratory

ORBITER RADIO SCIENCE (G. Pettingill, MIT, team leader)

Venus Internal Density Distribution	Dr. Roger Phillips JPL
Celestial Mechanics	Dr. I.I. Shapiro, MIT
Radio Occultation	Dr. Arvydas Kliore, JPL Dr. Thomas Croft, SRI
Atmospheric and Solar Corona Turbulence	Dr. Richard Woo, JPL
Atmospheric Drag	Dr. Gerald Keating NASA-Langley



INTERDISCIPLINARY SCIENTISTS

Interdisciplinary scientists have been selected for both the Multiprobe and Orbiter Missions to provide assistance in analyses of the Venusian atmosphere. They are:

Dr. Siegfried Bauer	NASA-Goddard Space Flight Center
Dr. Thomas Donahue	University of Michigan
Dr. Richard Goody	Harvard University
Dr. Donald Hunten	University of Arizona
Dr. James Pollack	NASA-Ames
Nelson Spencer	NASA-Goddard
Harold Masursky	U.S. Geological Survey
Dr. George McGill	University of Massachusetts
Dr. Andrew Nagy	University of Michigan
Dr. Gerald Schubert	University of California, Los Angeles



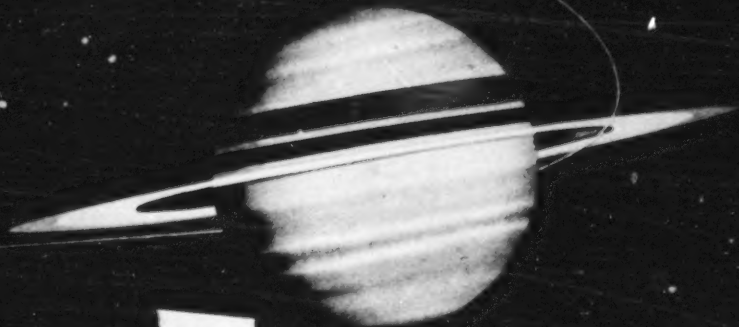
PIONEER ACCOMPLISHMENTS

(Pioneers 10 and 11 have made flights to Jupiter and are now, respectively, leaving the solar system and en route to Saturn. Pioneers 6 to 9 are still active solar orbiters.)

1. First trip to Jupiter (Pioneer 10).
2. First flight out of the solar system, Pluto's orbit crossing in 1987 (Pioneer 10).
3. First trip to Saturn; arrives Sept. 1, 1979 (Pioneer 11).
4. First spacecraft to traverse the Asteroid Belt and find it offers little hazard to spacecraft (Pioneer 10).
5. First spacecraft to fly high above Earth's orbit plane (100 million miles), measuring phenomena from 17° above solar equator (Pioneer 11).
6. Discovery of dipole character of the Sun's magnetic field, a basic finding believed to apply also to all main-sequence stars in the universe (Pioneer 11).
7. Discovery that Jupiter is an entirely liquid planet (Pioneer 10).
8. Discovery that peak intensity of Jupiter's radiation belts at 27,000 miles from the surface is many millions of times Earth's, but high-velocity passage at 107,000 mph by spacecraft is feasible (Pioneer 11).
9. First model of Jupiter's enormous, pulsating magnetosphere (Pioneers 10 and 11).
10. First measurement of massive fluxes of electrons accelerated by the moon, Io, which appear to be related to the source of Jupiter's huge decametric radio signals. Jupiter is the strongest radio source in the sky except the Sun (Pioneer 11).
11. Long-lived operational interplanetary spacecraft (Pioneer 6, launched December 16, 1965).
12. First analyses of the workings of the heliosphere, the Sun's atmosphere which extends beyond Jupiter (Pioneers 6 to 11).
13. First continuous reporting of "solar weather" by four stations around the Sun (Pioneers 6 to 9).

14. First occultation by the solar disc of a man-made signal source (Pioneers 6 and 9).
15. First accurate measurements of mass and densities of Jupiter's planet-sized moons, a key to Jupiter's formation history (Pioneers 10 and 11).
16. First closeup pictures of Jupiter, Jupiter's Great Red Spot, Belts, Zones and other features, showing details of atmosphere circulation (Pioneer 10).
17. First pictures and first closeup pictures of Jupiter's poles showing breakdown of belt and zone structure and localized atmosphere circulation there (Pioneer 11).
18. Findings that Jupiter's magnetic tail extends to Saturn's orbit; stream-stream interaction of the solar wind; Jupiter as source of high energy particles as far inward as Mercury; blocking of low energy cosmic rays from inner solar system (Pioneers 10 and 11).
19. Discovery that both the gegenschein and zodiacal light are neither Earth nor Asteroid Belt-related phenomena but due to evenly-distributed interplanetary dust, and that the "interstellar wind" enters the heliosphere in the plane containing the planets not from direction of solar system motion (Pioneers 10 and 11).

Pioneer Saturn (Pioneer 11) Encounter
September 1, 1979



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